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ABSTRACT

Evaluated is the present state of development of microcomputer and videodisc technologies as they relate to education. Factors which inhibit the entry of these technologies into education are identified, and include teacher preparation, availability of courseware, and cost. Areas are identified and strategies suggested in which federal and private agencies can have a positive impact in the development and implementation of these technologies. Appendices include a list of individuals and groups contacted for information on technolcgical development, references, and the author's relevant experience. (Author/CMV)

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IP

Microcomputers and Video Disc Systems:
Magic Lamps for Educators?

prepared for

The National Institute of Education

by

Ludwig Braun

Professor of Engineering

Assistant Director for Educational Technology
National Coordinating Center for Curriculum Development
State University of New York at Stony Brook

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Disclaimer

The attached report was prepared at the request of the National Institute of Education; however, any opinions stated herein are those of the author, and do not necessarily reflect the policy or opinions of the National Institute of Education or its staff.

ABSTRACT

The attached report has the purpose of evaluating the present state of development of microcomputer and video-disc technologies as they relate to education, and developing suggestions for areas where support is important.

Those factors which inhibit the entry of these technologies into education are identified.

Some areas in which federal and private agencies can have positive impact are identified, and structures are suggested for accomplishing these purposes.

The content of the report has been drawn from the author's experience, from the relevant literature, and from a series of visits to experts in these technological areas and in their application to education.

1. Purposes of Report

For generations, the term "educational technology" referred to textbooks and chalkboards. (Film and slide projectors widely available for more than twenty years, have had little impact on education).

Within the past decade, two technological innovations--the computer and the video recording system--have emerged, and have offered educators the opportunity to make dramatic changes in the educational environments of their students.

One of the major problems with introduction of these technologies has been the rates of development of technology in these areas. It is instructive to compare these rates with that of the development of the book. The book is the technological device which has had the most dramatic impact on the development of civilization in all of human history. It has been the major repository and transmitter of knowledge, ideas, and beliefs. The first mass-produced book generally is considered to be the Gutenberg Bible printed in 1454. Printed material was largely unavailable to the masses until the eighteenth century, when newspapers and circulating libraries emerged. This technological device took 300 years to become an integral part of our society.

The modern computer, on the other hand, didn't appear until about 1945. In the intervening three decades, the computer has become imbedded in every aspect of our society. The personal computer available only since 1975, offers the promise of placing information

processing capability in the hands of all U.S. citizens within the next 3-5 years.

Similarly, television has been available only for fifty years since the first public demonstration by Baird and Jenkins. Video-disc systems have been under development only for a decade, and first will become available to the general public in the last quarter of 1977.

The dramatically-different learning environments possible with personal microcomputers and video-disc systems, combined with the unbelievably-short-time-scale of their evolution have presented educators simultaneously with exciting possibilities for improving learning experiences for their students and with an almost insur-mountable challenge to adjust their carefully-developed educational systems(evolved over a time scale measured in centuries) within substantially less than a decade. We are moving from a society in which the focus has been on information transmission via books, chalk, and people, to one with a focus on information processing (in the most general sense) via computers and video storage systems, with people(teachers?) acting as mediators.

Out of this background of developments occurring at bewildering rates emerged a request by the staff of the National Institute of Education to assess:

1. the present state of development of microcomputer and video-disc systems.
2. the foreseeable future of these systems.
3. possible symbiotic relationships between these systems in educational applications.

4. those things which inhibit the entry of these tehnologies into the educational system.
5. possible supportive activities in which N I E might engage to convert these possibilities into realities.

The purpose of this report is to address each of these areas, in the hope that it will assist the staff of N I E, educators, manufacturers of systems, and developers of courseware.*

The information and ideas contained in this report have been extracted from:

1. A series of visits and conversations with individuals and groups active in development of these technologies.
2. The experience of the developer of the report.
3. Relevant publications.

In order to permit the reader to evaluate the contents of this report, the sites and people contacted are listed in Appendix A, this reporter's experience is described in Appendix B, and some useful references are listed in Appendix C.

* The term courseware will be used in this report to mean those materials which are useful in learning.

2. PERSONAL COMPUTERS

The term personal computer* has been applied, during the past two years, to computers which are sufficiently small and inexpensive that they are affordable by the individual person, and are used for a variety of personal purposes (education, entertainment, management of personal finances, etc.). It is that class of computers to which this report will be confined.

As we shall see, because of their price, size, and features previously available only on computers costing millions of dollars, educators, private individuals, and especially young people have learning environments within reach which were undreamed of only a few years ago. In a later section, we shall explore the impediments to this promise and at some approaches to their elimination.

2a. The History of Educational Computing

In the beginning (circa 1940) there was Aiken with Mark I, an electromechanical digital computer. In 1946, Eckert and Mauchly turned their ENIAC on for the first time.(ENIAC is considered to be the first all-electronic digital computer.); then came a succession of computers called Whirlwind, Hurricane,Zephyr, and Stretch. Finally, in 1954, Remington Rand offered for sale the first commercial computer. In the succeeding quarter century, announcements of new breakthroughs in computing hardware and applications have come with dizzying speed.

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* The term home computer sometimes is used as a synonym for personal computer.

During the period from 1954 to 1965, few educators used computers in their educational activities. There were many reasons for this, but among the most important were:

1. Few educators knew anything about computing; fewer still had thought about bringing this tool to bear on learning.
2. The cost of computing was so high that few educational institutions could afford to make such resources available to their faculties or students.
3. Most computers were operated in a batch-job environment for economic reasons. This focus on maximizing machine utilization resulted in very inefficient use of human intellectual power. (Imagine blowing into a clarinet or plucking a banjo string and waiting till tomorrow to hear the note you played!)

About 1965 Corbato at M I T and Kemeny and Kurtz at Dartmouth, among others, came to the rescue with time sharing systems. With this innovation, individuals were able to work interactively with computers (an enormously-important pedagogic advantage over batch processing),while the computers still worked very efficiently. Computing still was expensive, and was confined largely to universities; however, at about this same time the Pierce Report was published. It proposed an increased focus on the development of instructional applications of computers in education. In response to this report, the Federal Government (primarily through the National Science Foundation and the Office of Education) invested many millions of dollars in a variety of major national projects each of which had the objective of exploring specific facets of the overall problem.

A few of the major projects which explored this field during the years since 1965, were:

1. PLATO which developed impressive hardware and software and an extensive body of courseware*.
2. TICCIT which developed an interesting hardware delivery system, and a powerful courseware development system.
3. Projects Solo and Soloworks which have developed some novel ways of exposing high-school students to computers, as well as substantial amounts of mathematics courseware.
4. The Huntington Computer Project which identified a variety of ways of using computers in high-school science, mathematics, and social-science classes, including a substantial set of simulations in biology, physics, and the social sciences.
5. The Physics Computer Development Project which has demonstrated the effectiveness of interactive computation and graphic displays in undergraduate physics courses.
6. MATHLAB in which the computer assists the student with such common procedures as differentiation, polynomial factorization, and Laplace transforms.
7. LOGO, with its "turtle," which an elementary-school child can use to develop very complex algorithms for controlling the motion of the turtle, at the second-grade level.

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* The term software here refers to the system software (operating system, compilers, etc.); while courseware refers to user programs of various sorts which are employed in instruction.

8. CRICISAM, a calculus course, in which the computer supports the student in learning difficult concepts, and in developing the algorithmic approach to problem solving.
9. The CASE system and the Lister Hill Network, in which medical students diagnose and "treat" the computer (simulating a patient) which presents a wide variety of symptom-disease complexes.
10. IMPRESS which permits students to access a large social-data base, and to extract a wide variety of statistical reports from the machine without the usual difficulties of massaging data bases.

Space limitations prevent the citation of many more projects which have focussed on computers in education and which could be included in this list. Hunter et al (1) describe many of these in considerable detail.

Out of all these efforts, one may distill six major categories of educational use of computers. These categories fall into two major classes : teaching <u>about</u> the computer; and teaching <u>using</u> the computer as a tool (or medium, or environment). The six categories of use are:

1. Computer programming.
2. Computer science.
3. Computer literacy.
4. Computer-assisted instruction (C A I).
5. Computer-augmented learning
   a. Problem solving
   b. Development of algorithms

c. Simulations and games

d. Reorganization and retrieval of information

e. Mathematics laboratory

6. Computer-managed instruction (C M I).

Simultaneous with these events there was the development of a commitment by Digital Equipment Corporation and Hewlett-Packard to address the computing needs of educators in the learning sphere.* This commitment was aimed primarily at the low-budget pre-college educator who could not afford the rather steep charges required by the powerful time-sharing systems operated by universities and by time-sharing service bureaus. It was only because of these price breakthroughs that the innovative demonstrations cited earlier in this section were transferable into the classroom.

These companies made available stand-alone single-user minicomputers and mini time-sharing systems at prices which were low enough that educators could afford the purchase, and low enough that it no longer was necessary to keep the computer running full time in order to justify the cost (although, when such machines were installed in schools, students usually did keep them busy full time).

By 1975, it was possible to buy these minicomputers at costs approximating $5,000 per terminal.

In the January 1975 issue of Popular Electronics, the lead article described a computer (the Altair 8800)which one could buy in kit form for only $339. This article was the opening shot in what has

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* Few educators realize their debt to DEC and to H-P for this commitment which was both corporate and personal by such people as Dave Ahl and Eli Glazer of DEC and Jean Danver of H-P.

been a revolution in computer hardware--the advent of the complete, low-cost microcomputer. In the two years since the above article was published, over 25,000 microcomputers have been sold, dozens of companies have entered the market place with new computers, terminals, disc drives, speech synthesizers, D/A and A/D converters, audio-cassette-recorder interfaces, graphics systems, and other related devices.

By early 1977, it was possible to assemble a quite powerful computer for less than $2,000 total cost including a terminal and a mass memory device. This machine uses an excellent BASIC interpreter. Such computers now are quite reliable and execute programs at relatively high speed (e.g., up to five times as fast as the PDP-8). That the revolution is upon us is indicated clearly by several factors:

1. Publications. Prior to 1975, except for an occasional feature article in Popular Electronics, Radio Electronics, or 73, one had to go to the professional literature to read about microcomputers. This professional literature focused primarily on industrial applications of microprocessors rather than their integration into systems called microcomputers, and was incomprehensible to the educator and the amateur. Since 1975, several new, high-quality journals (including Byte, Dr. Dobb's Journal, Kilobaud, Personal Computing, and ROM) all have commenced publication and have aimed at the computer amateur and the educator; and, in addition, such "old-time" journals as Creative Computing (circa 1974) and People's Computer Company (circa 1973) have devoted a significant share of their pages to microcomputers and their educational and hobby applications.

2. Computer Stores. Prior to October, 1975, if one wished to purchase computer hardware, one went directly to the manufacturer (e.g., IBM, DEC, Data General), to a manufacturer's representative (usually just a sales office), or to a company which sold surplus computer hardware. The assistance which the purchaser could expect from any of these sources was (and is) minimal or totally non-existent. This was due, in part, to the very low ratio of salespeople to customers. In October, 1975, Lois and Richard Heiser opened a store called The Computer Store in Santa Monica, California. This is a retail store and is set up much like any other local specialty shop. Customers or potential customers are encouraged to drop in, to try out the demonstration units, to swap yarns, to seek help with a hardware or software problem, to attend classes on various computer related topics--and to buy computers (assembled or in kit form), peripherals, components, supplies, publications, etc. In addition, customers may bring their ailing computers to the Heisers for servicing. When this store opened, few thought it could succeed, but it has succeeded to the point where it has more than doubled its staff, and has expanded into much larger quarters. More important, though, than the success of the Heisers is the proliferation of such stores across the country. There now are over 250 such stores providing a variety of services to the consumer at the retail level. These stores are located in or near most major cities in the United States.

3. Computer Clubs. Prior to the first announcement of the Altair computer in January 1975, there were very few computer clubs nationwide. Most of those which did exist were established in high schools with computer access, and were concerned only with writing programs. None had more than a small membership list. Since then, hundreds of computer clubs have been founded all over the country, and have broadened their focus to include construction of computers, design of peripherals and interfaces, and unusual applications (ham radios, weather stations, etc.). The most spectacular of these new clubs is the Southern California Computer Club with a membership over 20,000 drawn from computer enthusiasts nationwide.

4. Personal Computer Shows. The national level of interest in microcomputers is measurable by the incidence of computer shows aimed at the microcomputer user, with focus on the amateur. In the Spring of 1976 MITS (manufacturer of the Altair 8800 and 680 computers, and the IBM--or DEC--of the microcomputer business) held its first annual national Altair meeting, and had several thousand attendees. In August 1976, the first Personal Computer Conference was held in Atlantic City with an attendance of 5,000. Personal Computer magazine has scheduled three regional personal computer conferences for 1977 and the First West Coast Computer Faire was held in San Francisco in April, 1977. The latter had a strong focus on educational applications.

In September, 1975, HummRo held an invitational conference to explore the computer needs of educators and to extrapolate current research trends one decade into the future. The proceedings of this conference recently were published(2). The major conclusion of this conference was that, well before 1985, there will be "zero-cost" computers,i.e., computer hardware which has negligible cost. This trend of costs has existed for several years in the calculator market and more recently in the electronic-watch market; and there is every reason to believe that microcomputer costs will follow suit as the annual sales volume increases.

As exciting and portentous as these developments were for education, there still was one major problem inhibiting the use of these machines. The microcomputers which were offered for sale prior to the end of 1976 were intended for the engineer and the hobbyist (indeed, they were called hobby computers). Most such computers were sold in kit form and required substantial skill in assembly and in testing to ensure proper performance.

Most educators were repelled by the thought of making decisions about which combination to choose from among the literally hundreds of alternatives available. They are not engineers nor hobbyists, and do not operate at the needed technological level. In addition, they are not prepared to accept delayed deliveries, inadequate performance, unfulfilled promises, and all the other difficulties which hobbyists have accepted as part of the price of entering this exciting new field.

To use an analogy, the educator who wishes to show a movie, wants to purchase a film projector which need only be taken out of the

box and plugged into an outlet. He will reject the use of film if he first is required to assemble the projector from its parts; or if he receives the projector complete except for the lens and the line cord. The hobbyist on the other hand, is willing to scrounge up an old line cord from somewhere, and to build a jury-rigged lens system so that he can use the projector.

Fortunately, in April 1977, at the First West Coast Computer Faire, the Commodore Business Machines Company (one of the leaders in marketing inexpensive pocket calculators) announced the first personal, or home, computer to be offerred for sale. This computer will be described in some detail in a later section (Section 2 C), but it is worth mentioning here that this computer costs only $595 comes completely assembled, and is designed for the non-technical home and school environment. During the Summer of 1977, Radio Shack also has announced an entry into this market, and other companies are developing systems to challenge these.

Before we proceed with a look at the present status and future prospects of personal computers, we digress to explore the inhibitions against the use of computers in education in order to determine the extent to which microcomputers will change educational computing.

2b. What Are The Inhibitions?

Despite all the efforts described above, the computer has not penetrated very deeply into the educational system at any academic level.* It is very difficult to determine the extent

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* There are, of course, a few notable exceptions, including: Dartmouth College, the University of California at Irvine, and at the pre-college level, the T I E S and M E C C groups in Minnesota.

of use of computers in education; however, many experts in the field estimate that 25% (about 8,000) of all high schools in the United Sates use a computer for educational purposes. As is so often the case, however, this is a misleading statistic. Most of these schools have only one or two terminals to service the entire student body. This means that the impact of the computer on most students still is negligible .*

There are many reasons for this lack of penetration. Among the most important are:

1. System reliability. Without doubt, the one thing which will turn even the receptive teacher away from educational technology is system unreliability. A teacher who, on three consecutive days, brings a film and projector into his classroom, only to have the lamp burn out, a fuse blow, or the projector chew up his film, is unlikely ever to bring a film into the classroom again. The same is true with the computer, whether the fault belongs to the telephone company, the computer manufacturer, the system operator, or some student who crashes the system.
2. Teacher preparation. Most technological devices (e.g., film projectors, cassette players, overhead projectors, and even video tape players) may be mastered by the teacher in

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* The author's children attend a high school with a 16-terminal minicomputer available. There are only a few school systems in the U.S. with more terminals available, yet, with an enrollment of 2,800 students, 70 terminals would be required to provide only one hour on the computer per student per week.

minutes, or, at the most, hours; whereas, the computer requires months for mastery--at least in the perception of the teacher. (In reality, of course, mastery of the computer is not required in many cases, as demonstrated by the Huntington Computer Project and the T I E S Project to name just two).

3. Cost. Until recently, the cost of purchase or annual rental of a single port into a computer was $5,000-10,000. Even the annual rental of a terminal to access a computer which otherwise is free, costs $500-1,000. Such expenditure levels, even in the best of times, put a severe strain on school budgets. (Typically,a high-school science department will receive a total annual budget for all purposes of $100-500).

4. Availability of courseware. In the typical classroom, the teacher cannot take class time, or his own limited preparation time, to develop computer porgrams for use in his class. He has neither the time nor the training to do this. In such cases, the availability of high-quality courseware is crucial to the successful utilization of the computer.

The importance of availability of large amounts of high-quality courseware was emphasized over and over again by every group or individual visited by this author. Every computer manufacturer who has serious designs on the educational market is searching actively for courseware authors.

5. Size. A dozen years ago this author used a computer in an interactive way in his classes. At that time, time sharing via a telephone line and a teletypewriter were required. Each class meeting it was necessary to move the teletypewriter (weighing over 100 pounds) from the fourth floor to the eighth floor and back. Even the stand-alone minicomputer didn't solve the problem. Although they are much smaller and lighter than conventional computers they still are too bulky and too heavy for easy portability.

6. Language. There is a great deal of confusion about which computer language should be used in an educational environment. A few candidates are: ALGOL, APL, BASIC, COBOL, LOGO, PASCAL, and PILOT. Each language has good and bad points, and each has champions and detractors (both usually are very vocal).

The controversy will continue to rage; however, Thomas Dwyer's advise to educators is:

> "Debate about these issues will continue of course, and that's a healthy thing. And someday there may be readily-available super languages. In the meantime, 'enjoy'."(3)

In succeeding sections of this report, we shall address each of these problem areas further, and shall attempt to identify possible solutions.

2c. The Present Status of Microcomputers

We indicated, in Section 2a, that a computer revolution was initiated in January 1975 with the introduction of the Altair 8800 microcomputer. In this section, we sketch out the dimensions of this revolution at the present time (August, 1977).

MITS, the developer of the Altair 8800, pioneered a new market into which many companies (mostly small) rushed. Among the "first generation" of microcomputers which survived the initial shakeout, in addition to the Altair 8800, were the Altair 680, the IMSAI 8080, and the Southwest Technical Products 6800. All of these computers are well made and provide adequate computer support for the typical classroom (pre-college or university). Although each has unique features, all perform at roughly comparable levels, and all cost in the order of $2,500-3,000 for a computer with 16 K bytes of random access memory (RAM), a keyboard, a video monitor and interface, and an audio cassette recorder (for mass memory) and its interface. The detailed characteristics of these computers have been described widely in company literature and in hobby computer literature (Byte, Personal Computing, Dr. Dobbs Journal, Peoples Computer Company, etc.). For this reason, these characteristics will not be detailed here. We shall reserve our space here for descriptions of more-recently-announced computers which have been designed for the home user to a much greater degree than the computers mentioned above, which were aimed at the hobbyist.

It is worth pausing a moment, at this point, to salute one of the pioneers in bringing microcomputers into schools--Dr. Peter Grimes of the San Jose Unified School District (4). Under Dr. Grimes' direction about a dozen microcomputers have been installed in San Jose schools. These microcomputers have been used to enhance the district's computing capacity at a cost significantly lower than would have been required to expand the existing mini time-sharing system.

Before we describe the characteristics of the newly-available "second generation" microcomputers, we shall digress briefly to indicate how far computing has come since 1945. Linvill and Hogan (5) compare the ENIAC computer with the Fairchild F8 microprocessor to which has been added 2K bytes of read-only memory (ROM), 8K bytes of RAM, and a teletype interface. The table below has been extracted from the Linvill article.

Characteristic	ENIAC	F8	Ratio
Size	$3{,}000ft^3$	$0.011ft^3$	$3x10^5$
Weight	30 tons	1lb.	$3x10^4$
Clock Rate	100KHz	2MHz	20
Add Time	200μ sec for 12 digits	150 μ sec for about 8 digits	equal
Mean Time to Failure	hours	years	10^4
RAM memory	1K	8K	8

Since 1975, there has been a gradual, but persistent, improvement in the reliability and capabilities of existing microcomputers plus the development of a wide variety of interesting peripheral devices (of which more later.) Suddenly, in April, 1977, at the First West Coast Computer Faire, there was an announcement

of a dramatic new product. Commodore Business Machines unveiled the PET 2001 microcomputer.

The announcement of the PET was dramatic for two reasons:

1. It was designed with the consumer and the educator in mind, rather than the hobbyist.
2. It was the first complete microcomputer (lots of memory, video monitor, keyboard, and audio cassette recorder, all with interfaces, plus the usual processor, power supply, etc.) available for under $600.

The engineers at Commodore established their system design to achieve these two objectives. The PET has the following consumer-oriented features, in addition to price:

1. Instant-on operation. There is nothing to load, no switches to set. When the power switch is flipped to ON, the system is ready to be used.
2. There is no elaborate, frightening (even though useful to the hobbyist) front panel with its arrays of LEDS and switches.
3. The system is completely assembled. There are no kits, and essentially no decisions to make (e.g., How many serial and parallel I/O ports should I buy; Which of all the available peripherals should I purchase? etc.).
4. Easy maintenance. The PET has a diagnostic routine loaded in ROM with which(it is claimed) any TV repairman can identify a defective board. The defective board will be sent to a board repair center for repair or replacement. This capability still must be measured in practice since

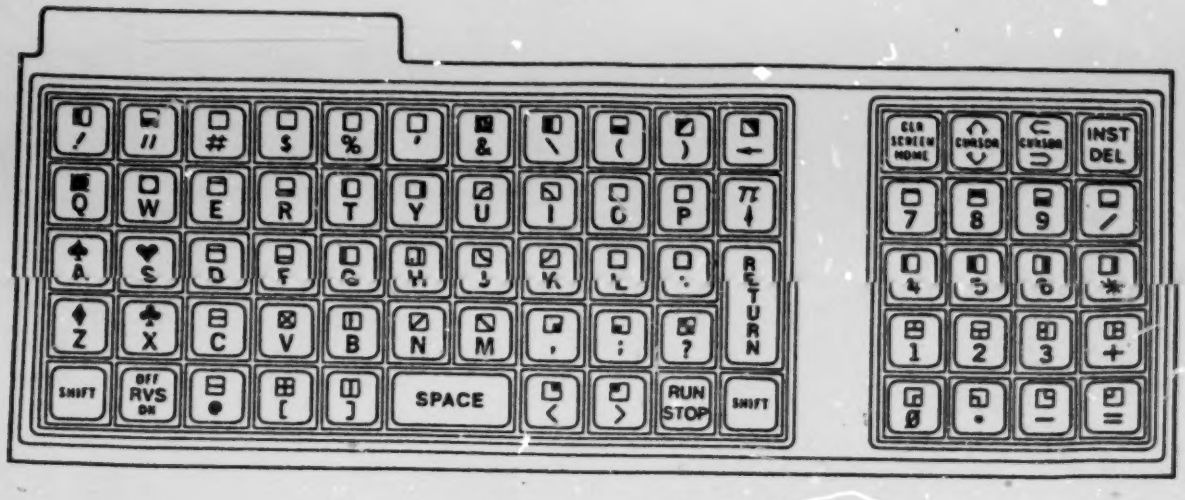
no machines have been delivered up to the time of this writing.

5. Almost all of the electronic components are mounted on a single printed-circuit board (there are only three total). This minimizes the number of connectors and interconnections in the system. Such minimization offers the possibility of significantly improved realiability over the "first generation" microcomputers.

The PET 2001 has the following characteristics:

1. 6502 microprocessor
2. ROM, 14 K bytes
   a. 8K BASIC
   b. 4K Operating system
   c. 1K Diagnostic routine
   d. 1K Machine-language monitor
3. RAM,4K bytes(minimum complement)
   a. 4K byte additional RAM,$200
   b. Maximum total RAM, 32K bytes with 24K B in an external enclosure.
4. Keyboard
   a. 73 keys
   b. Number pad

c. 64 ASCII characters plus 64 graphic characters (c.f., keyboard layout below for graphic-character set).



5. Built-in 1,000-baud audio-cassette recorder

6. Output ports.

   a. IEEE 488 instrument port

   b. 8-bit parallel port

   c. port for second audio cassette recorder

7. BASIC essentially is Altair BASIC,plus:

   a. 10-digit accuracy

   b. full cursor controlled editing plus software control of the cursor.

   c. file management on dual cassettes

   d. floating point plus integer arithmetic

8. SIZE

   a. 16½ in W x 18½in. D x 14 in. H (incl. monitor)

   b. 44 pounds total weight

Deliveries of the PET are promised beginning in September 1977.

By Christmas, the production schedule calls for 10,000 units per month produced in the United States. Commodore is negotiating with national retail chains (Sears and J.C. Penney have been mentioned in rumors as retail outlets for the PET, in addition to retailing through selected computer stores).

Commodore was the first company to announce a personal consumer computer, but it hardly will be the last. In July, 1977, Radio Shack (via Tandy Computers) announced a competitor of the PET. In addition, there are persistent rumors that Atari (the video-game pioneer), Texas Instruments, Coleco, and several chip-set manufacturers will join in the competition for this market.

The Radio Shack TRS-80 computer, whose characteristics are listed below, already threatens to provide strong competition for the PET in the consumer market place. Such competition may not be desirable from the viewpoint of the manufacturers, but educators certainly will benefit from price reductions and system improvements forced by it.

The characteristics of the Radio Shack TRS-80 computer are:

1. Z-80 microprocessor
2. ROM, 4K bytes, level 1 BASIC
3. RAM, 4K bytes (minimum complement)
   a. 4K byte addition, $99.95
   b. 12K byte addition, $289.95
4. Keyboard, standard keyboard, 53 keys
5. Interface for external audio cassette recorder. Data transfer rate, 300 baud.

6. BASIC is minimal.* It has simple graphic characters: 128 horizontal x 48 vertical definition.

7. Size

   a. 16½ in. W x 8 in. D x 3½in.H

8. Price, $399.95 for computer only, or $599.95 for computer plus 12-inch black-and-white monitor and audio cassette recorder.

Each of these computers has several advantages and several disadvantages for the educator when compared to the other. For the PET, these are:

PET Advantages

1. Excellent graphics
2. Excellent BASIC
   a. String functions
   b. Floating point and integer arithmetic. Ten-digit accuracy.
   c. File management system, dual cassette, named files.
   d. Software access to external devices.
3. Full cursor control for editing; software control of cursor.
4. Ports to access external devices
   a. eight-bit parallell port
   b. IEEE 488 interface
   c. Port for second cassette recorder
5. Keyboard advantages
   a. Separate number pad
   b. All alphanumeric characters plus all mathematical symbols available without shift key.

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* Few built-in functions:; no string commands, commands to access external ports, dimension statement, or function definition capability.

6. Hardware diagnostic routine in ROM

7. 8K byte BASIC plus 4K byte operating system

8. Program execution substantially faster than TRS-80.

9. Data transfer rate for cassette recorder, 1000 baud.

10. Distribution will be through selected computer stores, as well as through national department stores (Sears, Penny, or Macy's are possibilities).

11. The monitor, recorder, and computer form a single integrated unit which eliminates all cables. The user need only plug the computer into a wall outlet to be on the air.

PET Disadvantages

1. Keyboard too small(key-to-key distance only two thirds that of normal keyboard) for touch typists. Essentially a calculator-style keyboard.

2. Video monitor nine inches rather than twelve.

3. Memory expansions relatively expensive.

4. After first 4K byte memory extension, additional memory expansion requires external case.

5. 40-Character line on monitor.

6. Maximum memory, 32 K bytes.

7. PET more bulky that TRS-80.

8. No UL approval

Radio Shack TRS-80 Advantages

1. Professional-quality keyboard.

2. 64-character line on monitor.

3. 12-inch video monitor.

4. Memory expansion capability to 12 K ROM and 16K RAM internally.

5. Inexpensive memory expansion.

6. Approved by Underwriters Laboratories.

7. System may be purchased without monitor or recorder (if

purchaser already has these units).

8. Computer is about one-quarter volume of PET excluding monitor.
9. Maximum memory, 65K bytes.
10. Distribution will be through 146 Radio Shack stores nationwide.

Radio Shack TRS-80 Disadvantages

1. Level 1 BASIC is relatively weak.
2. Less versatile graphics.
3. Lower rate data transfer on cassette recorder.
4. Significantly slower program execution than the PET.
5. Monitor and recorder must be connected to computer by external cables before computer becomes operational.

Clearly, depending upon the viewpoint and needs of the purchaser, one or the other of these computers will be preferable. Frequently, the choice will be difficult; however, it is nice to have the choice.

There has been one interesting casualty in the new genre' of computer. Neither the PET nor the TRS-80, nor the other computers described below, uses the S-100 bus. The Altair 8800 uses a 100-pin bus called the S-100 bus, for interconnection of computing components, and until now was the standard bus for the microcomputer industry. Because of this bus universality*, a large number of peripherals (to be described below) has been developed for use in a wide variety of microcomputers.

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* The bus really isn't quite universal. Southwest Technical Products has built a microcomputer based on the 6800 which doesn't use the S-100. Even among those who use the S-100 bus, only about half the pins have been assigned.

At first glance, this rejection of the S-100 bus appears to be very unfortunate, because nom of the many S-100 compatible peripherals available may be used with the new computers. Although this is true, it may only be a short-term problem. If the PET expectation of selling 10,000 units per month is even roughly realistic, within six months there will be twice as many PETs as all other microcomputers combined and the PET bus will become the de facto standard. Because most companies marketing microcomputer peripherals are small, and consequently very flexible, they undoubtedly will respond quickly to the PET invasion, if it should occur.

Additional computers which have been announced since January, 1975 wich are attractive to educators are:

1. Intecolor 8051
   a. $3,995.
   b. 8080 micorprocessor
   c. ROM, 11K bytes, expandable to 32K bytes.
   d. RAM, 16K bytes, expandable to 32K bytes.
   e. 19 inch color video monitor.
   f. 80 characters/line x 48 lines,upper and lower case.
   g. Graphics
      I. 8 foreground and 8 background colors.
      II. Plotting on 160H x 192V grid.
      III. Software available for vector, bar plot, and point plotting.
   h. Powerful editing.
   i. Optional light pen($675 additional)

2. Apple II

a. $1,800 (for 16K byte RAM)

b. 6502 microprocessor.

c. ROM, 8K bytes, expandable to 12 K bytes.

d. RAM, 16K bytes, expandable to 48 K bytes.

e. no monitor or cassette recorder supplied.

f. 40 characters/line x 24 lines, upper case only.

g. Graphics

I. Plotting on 40H x 48V grid, 15 colors.

II. High-resolution plotting: 280H x 192V grid, 4 colors.

h. 1500-baud cassette interface.

i. game interface with two joysticks.

j. 6 K BASIC plus 2 K monitor in ROM.

These computers offer the educator color graphic as an educational tool, for the first time at a reasonable price.

The first color graphic device available for microcomputers is the Cromemco TV Dazzler, a single board which plugs into the S-100 bus, and which has a definition of 128H x 128V picture elements and permits the choice of eight colors in either of two intensities. Dwyer and Sweer(6) describe an interesting application of the Dazzler.

Another entry into the graphics arena is the Merlin terminal which may be used with most microcomputers. It has a black-and-white video monitor, displays 40 characters/line x 20 lines, and has graphics capability. The graphics capability is addressable through BASIC and has two plotting-density options:160H x 100V grid

(total cost $349); and 320H x 200V grid (total cost $403).

During the past decade, Dr. William Huggins of Johs Hopkins university has been telling the world (and demonstrating to it) how important graphic information is in the learning process. We have not understood well how to use graphics, nor have we been able to afford to generate any but the crudest graphic displays. Thanks to the efforts of Dr. Huggins, and others (notably, Drs. Zajac, Knowlton, Sinden, and Noll of Bell Telephone Laboratories, and Dr. Bork at University of California at Irvine), it now is clear how to use graphics, in at least some applications. It is only within the last two years, that the possibility has emerged of educators being able to afford graphic devices. Now the rest of us can follow the trail that has been broken by these pioneers.

The question of intelligent use of the color offered by Dazzler, Apple II, and Intecolor remains. Many people have an intuitive feeling that the addition of color will substantially increase the educational impact of computer graphics; however, the large cost of such systems in the past has prevented serious investigation of the effectiveness of color.

In addition to the foregoing graphics systems, the inexpensive large-scale-integrated (LSI) electronic devices and the new electronics cottage (perhaps garage is a better word) industry which it has spawned, have produced a number of interesting peripheral devices which have educational potential. Among these

are:

1. The most immediately-applicable new peripheral in the learning environment is a seven-channel D/A and A/D converter manufactured by Cromemco which costs under $300. Many educational games (e.g., Lunar Lander) and simulations (e.g., Charge--the Millikan Oil Drop simulation) will become much more realistic for the student. Young children can be trained to develop eye-hand coordination under the close, and flexible, control of the teacher. Through electromechanical sensors and effectors, students will be able to control directly processes for which they do not have the training or the dexterity directly. In addition, with such a device, the digital computer can be converted essentially to a very flexible analog computer (without the drift or scaling problems of real analog computers.)
2. In the Fall of 1976, two companies announced single-board speech generators which cost under $400, and are plug compatible with most microcomputers, and which produce a pseudo-human speech by stringing together the common phonemes under program control. The author has two grandsons who find the Telesensory Systems, Inc. Talking Calculator to be a fascinating way to explore number facts. An acquaintance of the author currently is exploring impact of this calculator on mentally-retarded children. Only very preliminary results are in, but they are very encouraging.

During 1977, speech-recognition boards have been announced. Heuristics Speech Laboratory has a board which can be "taught" to recognize any number of spoken words (depending upon available memory). This board costs $299 assembled.

The mind boggles at the thought of a computer which can interact with students verbally.*

3. It already is possible to enter visual information into a computer using another device made by Cromemco called the Cyclops camera. The Cyclops consists of a lens, an electro-optic sensor matrix in a 32 x 32 array and an interface board to convert the sensor signals into a form which may be dumped into the computer's memory. (This proposer has a group of students exploring the possibility of using this system to assist blind people to read printed material.)

4. Several companies have produced peripheral boards for generation of music. These range from simple devices which string together single notes into a melody to devices which permit the programmer to control attack, decay, and timbre of the sound in complex ways. Chamberlin (7) discusses a variety of ways of generating music with computers.

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* One of the most impressive projects at the Student Fair held at the 1976 National Computer Conference was a system consisting of a Wang Computer and a Votrax speech synthesizer (the Votrax costs $2,000) which presented arithmetic drill-and-practice problems and the computer's evaluation of the user's response, both verbally. This was the hit of the Fair and made that evening's TV news Broadcast

Almost every month, in Byte, Personal Computing, People's Computer Company, or Creative Computing, there is an announcement of a new peripheral device to do something no one ever considered before. Some of these are aimed at the computer hobbyist and some at the computer professional. Many of these are of potential interest to the educator, but most need development (at the level of the educational system rather than at the peripheral level).

Another development of some interest in educational computing is the emergence of time-shared microcomputer systems. At least two computer manufacturers (Altair and Cromemco) have announced the availability of time-shared microcomputers. It is impressive that people are able to accomplish this; however, this author wonders to what extent this represents doing something just becuase it can be done. One of the significant benefits which microcomputers from the Altair to the PET have brought to educational computing is the freedom from the problems of communication (primarily cost and unreliability) with the time-shared computer, and from the tyranny of the young computer freak who can crack any security system and get into other peoples' files for the thrill of mucking around where he doesn't belong.

In the judgment of this author, time sharing is essentially dead in educational computing. This may seem to be an extreme position; however consideration of the reasons for interest in time sharing reveals its correctness. Those reasons are:

1. Sharing of cost of computer hardware. With computer-system costs below $600, costs no longer need to be shared, especially when one considers that the annual cost

of rental of a telephone line plus a teletypewriter exceeds $600.

2. Access to large data bases. Until recently, only time-sharing and batch-processing machines had large data-file capability. The dual-cassette file management system of the PET, inexpensive mini-floppy disc systems costing less than $1,000, and video-disc systems make such access relatively easy to afford in the stand-alone system.

3. Inter-person communication. The capibility to access the files of others to leave messages and to read messages from others in one's "community" is very useful and intellectually powerful. In addition, inter-person communication permits the implementation of multi-person simulations of a high order of complexity.

This capability is easy with a time-shared system, but is possible also with stand-alone microcomputers equipped with modems (the Pennywhistle modem is an inexpensive device here). An experiment in such inter-person communication, called PCNET (Personal Computer Network) will be initiated in the Fall, 1977 in Palo Alto (8). Here a person wishing to communicate with another calls his computer and stores the message in the second person's computer memory.

In Section 2b, we identified the factors which have inhibited the entry of the computer into the educational environment. It is worth reviewing these factors, and determining the extent

to which microcomputers are able at this time to dispell them. The factors are:

1. System Reliability. The microcomputer holds out promise of significantly increasing the reliability of computer systems for two major reasons:
   a. Because of large-scale integration, and because of the trend toward single board computers, interconnections are made permanently and internally, resulting in few failure in connections.
   b. Because computing has become sufficiently inexpensive that time-sharing no longer is necessary, the unreliability added by telephone lines, modems, time-sharing hardware, and computer freaks may by eliminated.
2. Teacher Preparation. Clearly, no development we have mentioned has any effect on this problem area, except, perhaps by providing motivation to the teachers.
3. Cost. The PET and the Radio Shack TRS-80 computers have made dramatic inroads on elimination of this problem.
4. Availability of Courseware. Although we have not unveiled any development which addresses this inhibition directly, the promise of sales of 100,000 computers per year in the immediate future has attracted the attention of many potential courseware authors. This attention should help to alleviate this problem.
5. Size. We still do not have quite the briefcase-size

computer; however, the PET and the TRS-80 are very portable. This portability is very important in education, because the computer now may be brought into any classroom with a wall outlet. Another important aspect of this portability is the ability which it provides to carry the computer anywhere--including permitting students to take them home over night or over a weekend. The teacher also may take the computer to his office or home to develop his own expertise in privacy.

One possible future for such computers involves local libraries. Many libraries currently are much more than repositories for books, and offer their patrons paintings, records, video cameras and recorders, and other devices. One can imagine local libraries circulating PETs to their patrons in the future.*

6. Language. None of the developments which we have mentioned has impacted language development; however, we shall address this problem in a later section.

We have reviewed here the present status of microcomputers. There are many computers and many peripheral devices which have not been mentioned, or which have been mentioned only in passing. These omissions have been conscious, and were made in order to keep the size of this report within reason. Those systems and devices which have been described were included to develop

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* The author's local library has two time-shared computer terminals for use by local residents.

a perception of the leading edge of hardware developments through the Summer of 1977.

In the following section, we shall explore the future, to the extent that it can be perceived.

2d. The Future

"We see through a glass, darkly", the Scripture writer said. It is difficult also to predict the character of the classroom a decade hence, or the role of the computer in it.* It is difficult even to predict what this computer will be able to do, or how much it will cost, in view of the dizzying pace of developments since January, 1975.

The microcomputer era upon which we are embarking already has been characterized as the era of the personal computer. It certainly will be that, but it promises to be much more. Educational and social historians someday may look upon January, 1975 as the start of the time when the computer enabled humans to expand their intellectual powers beyond our present comprehension.

Even though it is very difficult to make predictions in this area, we shall sketch out the likely dimensions of the near future.

Theodor Nelson (9) predicts that by 1980 there will be computers in 10 million American homes.

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* There are those visionaries who predict that classrooms will disappear within a decade--or two at the most--and that all learning will take place in the individual home setting, and that the computer will play a central role. Although this is a possible outcome, it isn't a likely one.

Venture Development Corporation of Wellesley, Massachusetts recently published a two-volume study of marketing and business aspects of personal computers. The findings of this study have been summarized by Kaplan(10) who states that:

1. Between January,1975 and January,1977, 25,000 microcomputers have been sold.
2. Annual revenues will increase by 14.5% per year. In 1976, revenues were $9.7M , while in 1981, they are expected to be $57M.
3. A $1,200 system can sell 8,000-25,000 units in two years; while with a $600 price, 18,000-55,000 units will be sold in two years.

In order to indicate the nature of the future we list below some recent predictions about hardware developments:

1. Alpha Data Inc. of Chatsworth, California has announced a charge-coupled-device (CCD) solid-state "disc", called the CCDISC. Its average access time is 250u seconds, and its capacity is 128 K byte-1M byte. In small quantities, a 1M byte unit costs $17,000. or 0.2¢/bit.
2. Panigrahi (11) describes a variety of applications and configurations for CCD and bubble memories. He points out that these systems "are not direct replacements for discs, but rather new system components.....".
3. Noyce (12) predicts 65K bit-131K bit memory chips with 100 nano-second access time by 1981, and 1M bit chips by 1985.
4. Petritz (13) predicts a single-chip 32-bit processor with 1M bit of memory on board by 1985.

5. John and Volk (14) describe a complete microcomputer built from only three chips. This computer has an 8080-type processor, a serial and multiport-parallel I/O interface, interrupt controller, timer, 256 bytes of RAM, and 2,048 bytes of ROM.

6. Japan will seriously challenge the U.S. semiconductor industry in the near future. Among their developments are:

   a. 10K-50K-gate chips and 1M bit memory chips are under development.

   b. Their LSI chips cost only 40% of U.S. units.

   c. They are spending $250M-$1.5B on developments in IC components.

   d. 262K bit RAMs and one-chip 32-bit microprocessors (with 32K bytes of on-board RAM) by 1981-83.

   e. 65K-bit RAM chips and 16-bit microprocessors with 4K byte on-board RAM by 1979.

7. Hitachi of Japan(16) has under development an LCD panel with four rows of 32 characters using a 5x7 dot matrix on a panel 38mmx175mm(1.5inx7in.),and soon will have an 8 row unit.

8. Texas Instruments (17) has a 92-kit bubble chip available which is already cost competitive with floppy discs. In quantity, a bubble chip interface costs $75. Bubble memories have higher reliability and lower error rate than either fixed-head or floppy discs. They also have faster access time, lower power requirements, smaller physical size and simpler interfacing; but have lower transfer rate than floppy discs. In addition, to change

the data set to be accessed on a disc, one need only change the diskette which costs only $5; whereas changing a bubble chip still is quite difficult and expensive.

A bubble "disc" is compared with the Shugart mini-floppy disc in the table below.

Characteristic	Bubble "disc"	Shugart
Cost incl.interface	0.08¢/bit	0.3¢/bit
Transfer rate	44K bits/sec.	125K bits/sec.
Avg. access time	4ms	463 ms
Weight	0.7 lb.	3 lbs.
Volume	38 cu.in.	150 cu. in.

9. Philip Roybal of National Semiconductor feels that there will be plug-in bubble memories by 1981.

10. Jim Warren the editor of Dr. Dobb's Journal of Computer Calisthenics and Orthodontia in Menlo Park, California predicts that:

    a. Magnetic bubble and CCD memories will replace floppy disc within two years.

    b. There will be networking of personal computers for memory sharing, program files, etc.

    c. Personal computers will serve as a communication channel for handicapped people.

    d. Computer system prices may not drop in the future, but system capabilities will increase. Chuck Peddle of Commodore (designer of the PET) agrees. He points out that the cost of black-and-white monitors, cassette recorders, and keyboards are as low as they are likely to get; so they place a floor under prices of systems.

    e. Speed increases by a factor of 10 will give us real-time graphics and speech synthesis.

    f. New display technologies will emerge (flat-screen and LCD).

g. Better languages will be developed (we shall adress this matter in a later section).

11. Alan Kay of Xerox Research suggests that RAM may be in head-to-head competition with bubble memory for mass memory. The volatility of RAM may be overcome relatively easily as standby power requirements drop. Battery back-up power makes them essentially non-volatile.

12. A holographic microfiche read-only-memory system has been announced with 25M byte capacity, and with a projected retail cost of $500.

There is no doubt that the next few years will see exciting developments in microcomputer systems, even though it is difficult to perceive exactly the form of these developments. This difficulty is exemplified by the situation prior to the announcement of the PET in April, 1977. Many people have been predicting that a complete computer system would be offered for sale for well under $1,000;however, most of these people felt that such a computer wouldn't surface for two or three years. Even one month prior to its announcement, no one expected the PET.

Will there be another dramatic breakthrough like the PET next month? in six months? two years? It is impossible to guess, but whenever it happens educational computing will make another large stride forward.

Perhaps the ultimate in personal computing is Alan Kay's Dynabook (18),which is a notebook-size computer which will permit dynamic interaction between the user and a vast information base.

3. VIDEO-DISC SYSTEMS

Video-disc systems will be considered in detail by Dr. Dustin Heustin in a companion report. Here, we look at the video disc as a part of a personal total-information system in conjunction with a computer. For completeness, we shall describe briefly the history and present status of video-disc systems prior to exploring the possible interactions between computers and video-disc systems. The reader who is interested in more detail on video-disc systems is referred to Dr. Heustin's report.

3a. History of Video-Disc Systems

Remarkably, the history of video-disc recording goes back to 1927, when John L. Baird engraved video signals on a gramophone disc, in much the same way that audio signals were recorded. Baird was limited by the technology of his time to a 5,000 Hz bandwidth. As a result his pictures had only 30 lines and 15 black-and-white elements per line. Even though the resolution was poor, Baird deserves a great deal of credit. It took most of the ensuing half century and legions of engineers to bring to practical implementation the concept which he pioneered.

The next major step in recording of video images occurred in 1956 when Ampex announced magnetic-tape recording of video images. The major technological breakthrough here was the frequency modulation of the video signal prior to its recording. Because frequency modulation is amplitude independent, the video signal essentially is

recorded in two-level, or binary, form. This concept has been employed in at least some of the modern video-disc systems to be marketed in the near future.

Since that time, several companies have worked intensively on the development of video-disc systems using widely differing approaches. Among these companies are Telefunken-Decca, RCA, Philips, MCA, and Thomson-CSF. The system developed by each of these groups is described by Benson (19). Wood and Stephens(20) describe briefly the operation of the Telefunken-Decca and Philips/MCA systems. The Philips/MCA system is described in some detail by Kenney(21),Bögels(22), and Kohler (23).

We are about to enter the next chapter in the history of video-disc systems--the market place struggle for dominance. The developers of each system think that theirs is best. It probably will be several years before consumer interest in such systems is established, and before one or another system wins out over the others. (Unfortunately, all of these systems are incompatible with one another.)

Philips/MCA is planning to test market their system in the Mid West in the Fall of 1977 prior to national distribution in 1978.

Thomson-CSF is planning to begin marketing their system in Europe in 1978.

3b. The Philips/MCA Video-Disc System and Education

There essentially are two kinds of video-disc systems: The electromechanical systems in which there is mechanical transduction (hence physical contact); and electro-optical systems in which the contact with the disc is optical (usually a laser beam). The RCA and Telefunken-Decca systems are examples of the former, and the Philips/MCA and Thomson-CSF systems are examples of the latter. In this report, we shall focus on electro-optical systems because of their educational advantages (outlined below); we shall focus specifically on the Philips/MCA system because it will enter the American market place first and is likely to dominate this market for this reason, and because it appears to be superior functionally to other systems.

In the Philips/MCA system, during normal play, the disc rotates at 1,800 rpm. It has 54,000 tracks each containing a single frame of video information encoded in NTSC format. This provides thirty minutes of video program time per side.

Because each frame occupies an entire track, there is one frame per revolution of the disc. As a consequence, it is possible to use the system as a slide projector in the stop-frame mode by jumping back one track at the end of each revolution; hence, the image stays still. It is possible also to generate slow motion either forward or reverse by controlling the motion of the read head.

This system records the video signal in binary form by frequency

modulation (as in the Ampex system). It is worth looking briefly at the information storage capacity of this disc from several viewpoints. These are:

1. It is possible to store 54,000 individual slides on one disc side using the stop-frame mode.

2. By compressing the audio signal by an effective factor of 300 before recording and then "uncompressing" by the same factor on playback it is possible to store 150 hours of music or other audio information on one disc side (21).

3. Kenney (21) proposes a talking encyclopedia containing 27,000 slides and 75 hours of commentary.

4. Because the information is stored in binary form, there is a total capacity of 185,625 bits per track, or 1.25 billion bytes per disc side!

This enormous capacity is available as a read-only-memory for storage of data or computer programs. It also is possible to store information contained in books in binary form (one byte per character).

The Encyclopedia Britannica consists of 15 volumes with about 1,000 500-word pages per volume. This represents a total of 50 million characters of information. At one byte per character, the Encyclopedia Brittanica could be stored in 50M bytes of memory, only four percent of the capacity of a single disc.

Looked at from another viewpoint, one disc probably could contain all the computer-based educational courseware which ever has been written.

Because the video-disc systems are aimed at the consumer market, the signal encoding has conformed to the NTSC standard waveform. If educators are to be able to take advantage of the cost benefits of large consumer demand, they must conform to this same NTSC standard. This means that special interfaces are required between the information source and the disc, and between the disc and the computer or other information medium. Kenney (21) discusses these constraints in some detail.

In the Philips/MCA system, if the focussing arm is stationary, the tracking mirror can address any one of 100 tracks, and can move from any track to an adjoining one in 60 microseconds. since 186K bits may be stored in one track, 100 tracks can contain 18.6M bits (or about 2.3M bytes) of information. This is 20 times the capacity of a mini floppy disc. The table below compares the capacities of video discs with full track utilization, video discs using only 100 tracks, and the North Star mini floppy disc (one of the most popular discs in the microcomputer field).

Characteristic	Video disc full cap.	Video disc, 100 track	Mini floppy disc
Total capacity	1.25×10^{3} M bytes	2.3M bytes	100K bytes
Transfer rate	7M bytes/sec.	7M bytes/sec.	16K bytes/sec.
Cost/bit	6×10^{-8} cents	4×10^{-5} cents	5×10^{-3} cents
System cost	$500+interface	$500+interface	$700
Disc cost	$2 (lots of 1,000)	$2 (lots of 1,000)	$5
Avg. access time	5 sec.	3 millisec.	463 millisec.
Error rate	10^{-9}	10^{-9}	10^{-8}-10^{-11}

A brief look at the table above reveals that the 100-track video-disc system is clearly superior to the mini-floppy-disc system by at least an order of magnitude in capacity, transfer rate, and access time, with system cost, disc cost, and error rate being comparable in both systems. The only significant disadvantage of the video disc as a mass memory device is that it is read-only memory, whereas the floppy disc is read/write memory.

One potential drawback of the video disc is production of copies. The replication equipment is sufficiently expensive that few schools will be able to justify the cost; however, both Philips and MCA are planning to establish replication centers at several locations. A customer must submit a video-tape master with the information (pictures, data, etc.)

encoded in NTSC format. The replication center will make a disc master for about $1,000 and will make disc copies for $1 each; thus 200 copies will cost $6 each, and 1,000 copies will cost $2 each. It should be noted that these costs represent only the replication cost, not the cost of generating the information to be stored on the disc.

3c. Educational Applications of Video-Disc Systems

Unfortunately, partly because video-disc systems are new, and partly because few people have had any access to such systems, there has been essentially no development of educational applications-- indeed, there has been little detailed thought devoted to such applications. Mr. James Baker, of the U.S. Army Research Center, who is responsible within the Army for video-disc applications, feels that the only people in the United States who are doing significant work in this area are Dr. Robert Brantsen of Forida State University and the WICAT group in Utah under the direction of Dr. Dustin Heustin and Dr. Victor Bunderson. The WICAT work will be described briefly below (and it will occupy a significant part of Dr. Heustin's report to NIE).

In the author's search of the literature and in discussions with people around the country, the following areas of educational application of video-disc systems have emerged:

1. Linear video. Here, the video disc is used in place of movie film. The cost of a 20-minute educational film is well over $200; even rental of the film for a single showing costs $15-25. The estimated purchase cost of a video disc film is $10-15. Even if this were the only educational application, it would be exciting, because a school can build a "film" library for less than the present rental budget. In addition, the teacher has the capability to achieve fast forward, and easy reversing, which are not available with film projectors.

2. Archival storage. Because of the large capacity of video discs to store information, and their low cost, they are very attractive as a medium for storage of computer programs and data files, and for storage of books, journals, and other printed materials. Because discs are compact, and inexpensive, and because the information they contain is easily accessible, they make an ideal medium for reference materials for home and classroom use, as well as for community libraries.

3. Programmed instruction. The possibility of combining motion and still frames in full color with text and audio, is a very exciting alternative to more conventional programmed texts. Clearly, the courseware developer has a much more flexible and powerful tool than he ever has had with paper and printing press. Drs.Heustin and

Bunderson and their WICAT group in Provo, Utaha are developing an experimental video-disc programmed "text" in high-school biology for the McGraw-Hill Book Company, as well as conducting a study for the Mormon Church on the feasibility of using this medium for remote training of church officers stationed all over the world.

The approach of Feustin and Bunderson is similar in educational philosophy to the TICCIT system developed by Bunderson under NSF support. The approach is described by Bennion and Schneider (24).

4. Interactive use with a computer. Dr. Alfred Bork of the University of California at Irvine suggests (25) that a video disc will contain a complete multi-media teaching package. Such a package might include a color video sequence presenting relevant historical background and pertinent information to set the stage for a complex computer simulation of some phenomenon in biology, chemistry, or physics. After the video sequence, the disc would contain the simulation program which would be loaded into the computer memory for subsequent execution. During interactive execution of the simulation program, and depending upon the student's actions, the computer will call upon the video disc to help it to generate appropriate supporting graphics, or an audio sequence, a background still frame, or even a new computer program. After the simulation is complete, the computer will call a testing program from the disc and check the depth of the student's

understanding of the phenomenon he has just investigated. Depending upon the results of this test, the computer might call up another simulation (more or less complex, depending upon the student's performance), or a terminal video sequence, as dictated by the strategy of the courseware developer.

One significant advantage to the teacher of this approach, in addition to the obvious pedagogic advantages, is the ease of use. Only a single disc need be loaded, rather than a computer program, a slide carousel, a film, and an auio cassette, each separately, and each into a different machine.

The possibilities for educational impact with video-disc systems indicated in the four items above are very exciting--especially item 4. It should be pointed out, however, that the consumer video-disc player to be offered for sale starting in late 1977 will not have the capability to interact with a computer as indicated above. With that player, fast forward and reverse are executed under manual control. The disc has track numbers stored on each track. These numbers are displayed on the screen during the search mode;however, the user must stop the player manually. A video-disc player must become available which can communicate directly with a computer, telling the computer which track it currently is reading, and accepting a command from the computer telling the player the next track to read. In this way, the player is under direct and continuous control of the computer

and the courseware developer can design into his computer programs the logical control needed to direct the video-disc player according to the needs and desires of the student. Philips and MCA are working independently on players for the educational and industrial users. These units are a year or two away, and are expected to cost in the order of $1,000-1,500 when they become available. It is expected that these so-called E/I players will have a local microprocessor and some local memory to achieve the interactions described above.

The video-disc systems which have been described above have great potential for education as stand-alone devices and as part of an information-processing system in conjunction with a computer. This potential must remain latent until educators are able to obtain video-disc systems and are able to obtain access to mastering systems to produce special-purpose discs.

Educational applications of video-disc systems will be developed in stages, as first consumer players and then E/I players become available.

The overall impression received by this author in all of his contacts related to video-disc systems is that educational developments in this area are in a much more primitive state than is the case with microcomputers. Few educators are aware of the existence of video discs; fewer still have given any thought to how they might use such systems to improve the learning environment of their students.

3d. Inhibitory Factors with Video-Disc Systems.

Because video-disc technology is so new (it still isn't quite here for most of us), less thought has been given to the inhibitions against its entry than is the case with computers; however, we do have experience with the problems of introduction of other technological devices (film projectors, slide projectors, audio cassette recorders, computers, etc.). Based upon this experience, we may speculate on the nature of these inhibitions. These are:

1. System reliability. The problem here will be identical to that with other technologies. The system reliability must be very high if the teacher is to have sufficient confidence in it to bring it into his classroom.
2. Teacher preparation. The required level of teacher preparation for use of video discs will depend upon the class of application as described in Section 3c above. In the linear video mode, no preparation will be needed other than that required in the use of films, slides, etc.

   Archival-storage applications will require some teacher preparation, but it should not be a major problem.

   The programmed-text mode and interaction with a computer, on the other hand, will cause significant departures from conventional classroom practice, and will require substantial amounts of teacher training.
3. Cost. The cost of the player is comparable to that of film projectors and the cost of discs is significantly lower than that of films and slides; as a consequence,

cost is unlikely to inhibit entry of these systems into schools. On the contrary, the cost is low enough compared to the alternatives that use of video disc should be encouraged.

4. Availability of courseware. Because of the difficulty of mastering and copying of discs, as well as the need for complex video and electronic equipment for generation of the master tape, teachers must depend upon commercial sources for courseware. Development of courseware for interactive computer applications undoubtedly will require teams of experts for its development.

In Section 4, we shall attempt to identify some ways of removing these inhibitory factors, so that educators will be able to take advantage of the exciting characteristics of video-disc systems.

4. HOW DO WE BREAK THE LOGJAM?

There are exciting days ahead for educators and especially for students. When we rub the magic lamp to free the genie--the personal information system --we shall enter into an era of individual intellectuality that few people even have imagined. In this section, we shall look at the kinds of strokes we must use to free the genie.

4a. Courseware Development.

The single problem identified by everyone concerned with educational computing as a critical one is the lack of high-quality courseware. Ahl(26) points out one aspect of this problem. In 1975, the ratio of the cost to program one line of code to the cost to execute that line of code is 10^8 ! This does not include the cost to generate the support documentation required for educational courseware.

Dr. Andrew Molnar (27) of the National Science Foundation points out that:

> "the high cost of development of quality curricular materials remains as the last major financial barrier to the widespread use of computers in education."

He proposes that a "theory of production" for computer-based curriculum material may be more important than a theory of learning in its impact on education.

In a companion paper (28), Molnar states:

> "Numerous national studies have all concluded that the lack of good computer-based material is the major obstacle to the widespread use of computers."

There are people all over the world developing computer-related courseware. Much of this effort is wasted, because most of what is done has been done over and over again elsewhere. The cost in money and people-hours represented bythis re-creation of materials is phenomenal, and, if re-directed into useful avenues, would have a dramatic impact on education.

Molnar points out that Arthur D. Little, Inc. has noted that the high marketing costs needed to penetrate fragmented markets in education are prohibitive. They have recommended that the federal government can prime the pump for commercial innovation by taking the lead in defining the needs and aggregating a market demand in this area.

Molnar points out, in conclusion, that a federally-supported national curriculum effort is urgently needed.

Molnar (28) describes a study by Batette Laboratories of innovations with high social impact. They identified four factors which were essential to success:

1. The existence of a technical entrepreneur was the most important factor.
2. Recognition of a technical opportunity and of a technical need to be filled.
3. External funding (particularly government funding) was instrumental in the direct support of most of the innovations studied.
4. The confluence of other technology (here, the video disc comes to mind) was important.

He suggests that current federal managerial thinking is inadequate to the task at hand, and that a new innovative organization is required. One example of this managerial thinking is the treatment accorded by the federal government to almost all of the technical entrepreneurs in educational computing. This author knows most of these people, and has seen them cast out just at the point where they really got rolling. The justification has been that they were supported to demonstrate a principle, and, having done that, they no longer needed support from the federal government, but should seek support for continuation from commercial publishers. Unfortunately, the publishers have not been able to pick up the ball, because the market isn't adequate yet to support profit-making organizations.

Bork points out that courseware development currently is a cottage industry with individuals essentially doing solo efforts at writing courseware. Every major computer curriculum project which has existed since 1965 has discovered the need for teams to develop courseware units. The areas in which expertise must be brought to bear are:

1. Subject-matter.
2. Classroom practice and constraints.
3. Programming.
4. Educational psychology.
5. Writing of support material.

The individual who has capability in all of these areas is extremely rare, and, so, it has been necessary to assemble teams of people

to create courseware.

The need for quality courseware may be satisfied by a two-step approach:

1. Support for courseware-development groups. This support should be distributed among groups with a proven track record, but new "technical entrepeneurs" should be included also.

2. There should be an effort made to collect,evaluate, and improve existing courseware. There is a great deal of courseware in the field, some of which is excellent, but most of which needs improvement especially in support documentation. It will require a concerted effort to locate, improve, and make available this largely-untapped resource.

3. A mechanism must be developed for distributing courseware. Currently, a teacher attempting to collect courseware for his students must consult Hewlett-Packard, Digital Equipment Corporation, the ERIC files, the teachers' journals in his field, directors of computer projects (past and present), and teachers in other local schools. This requires sufficient effort that few people are willing to expend it. A centralized mechanism for collection and distribution of courseware must be developed. In this way, it will be relatively easy for teachers to access existing materials.

Another important element of such a mechanism is the distribution of program updates. Computer programs contain bugs which crop up at random times. It is important to establish a means for communication of program updates to users. Preferably, this should be automatic using subscriptions to a newsletter, or catalog, or some similar mechanism.

4b."Consumers' Union" for Educators.

In the "old" days of educational computing (circa 1970), the educator had only a few options available in the purchase of computer power. There were only two or three computer manufacturers to consider seriously, and perhaps only a single time-sharing service to include. Even then, the decision often was made on the basis of the relative persuasion capabilities of the salesmen involved rather than on the merits of the several alternatives. This occurred primarily because few educators understood computer systems well enough to make an objective evaluation.

With the advent of the microcomputer, the problem is compounded. All the 1970 options still are open, and, in addition, there are at least ten microcomputers competing seriously for shares of this market, and fifteen companies with new computer designs. Some of these companies* are legitimate and are very conscious of their reputations, while others exist under someone's hat (or

* No company which currently is competing seriously for this market is a large company. H-P, DEC, and IBM all offer microcomputers, but their pricing and performance haven't yet caught up with the "Altair phenomenon."

garage) and appear and disappear rapidly. The educator (particularly at the pre-college level where computer expertise is rare) needs help in sorting through all these alternatives. Especially, he needs help in avoidance of traps set by sweet-talking salesmen or advertisements.

The needed assistance can be provided by establishing a Consumers' Union-like center to:

1. Evaluate existing microcomputers and peripherals.
2. Identify consumer-related problems such as false claims, long-delayed deliveries, maintenance and repair difficulties, etc.
3. Explore new ways of applying such devices in learning environments.
4. Communicate its findings to educators.
5. Identify for manufacturers the needs of educators, and improvements in their systems which will make them more useful to educators.

Here, again, there is a need for formalization of a communication channel to the educator through a newsletter, or similar means.

4c. Languages

There is a continuing controversy over the "best" language to use for educational courseware. At the high-school level, the most popular language in use is BASIC, even though many people agree that there are problems with BASIC. Even if BASIC were perfect there still would be a serious problem because of the

many dialects of BASIC which exist. One of the major computer manufacturers offers BASIC on most of its computers, but there is no standardization even among the versions of BASIC on its machines--in fact even on a single model of computer, ther are several incompatible versions of BASIC.

There is a need for a careful study of language needs for courseware. What are the educational applications for which LOGO is best? The same questions must be answered for APL, PILOT, BASIC, etc. There also is a need for the identification of problem-oriented languages for special classes of users. SCORTOS (29), a music-oriented language, is a good example of such languages. Another special-purpose class of languages for authoring of courseware is needed to simplify the conversion of an author's ideas into an executable form.

Any language-development effort which is mounted must recognize that the language must be designed so that the user may implement whatever he wishes (algorithms, musical scores, etc.) in a way which is transparent to the user. In addition, such language development must include transferability of materials. The average educator does not have the time or the expertise to change all of the trivial program discrepancies from one dialect of a language to the one which will run on his machine. The user must be able to take an available piece of courseware and drop it into his computer with confidence that it will run. (It may be that this will be possible only through a courseware distribution center such as that proposed in Section 4a.) Bork(30)

addresses this problem of transferability at some length. In this paper, Bork proposes "Bork's First Rule":

> "The more systems the computer-based materials can run on, the less interesting pedagogically the materials are."

If Bork's First Rule is valid (and it might very well be), then the courseware distribution center will be essential.

There has been a great deal of discussion of languages in the recent literature. The interested reader should consult references 31-40.

Wally Feurzeig of Bolt, Beranek, and Newman, and one of the developers of LOGO, stresses the importance of looking critically at the advantages and disadvantages of all the available languages, in an educational setting.

Thomas Dwyer urges that compilers be implemented for microcomputers, in addition to already-available interpreters, in order to provide substantial improvements in system speed. Ideally, the user would have both compiler- and interpreter-oriented languages available on his computer in order to permit him to take advantage of the characteristics of each.

4d. Conclusion

The focus of Section 4 up to this point has been on microcomputers. Most of these comments include the video disc as a ROM, and as a component of an interactive personal information system. Other applications of video discs are the focus of Dr. Heustin's report and will not be considered further here.

We find ourselves in a very difficult situation in educational technology, in general, and in computers in education in particular. The pace of technological development is accelerating; the cost, reliability, and performance of microcomputers are improving at a phenomenal rate. During the same period of time (1975-1977) as computers at last are within reach of most teachers, funds for support of development of curricular material and educational research in this area have essentially dried up in both governmental and private sectors.

In preceding parts of Section 4, we have identified several aspects of the solutions to the problems of encouraging penetration of technology into the educational system. These solutions involve substantial levels of financial support--support which must be made available for extended periods, (perhaps five years, and certainly no less than three) if satisfactory results are to be expected.

It is difficult to estimate the necessary financial commitment required; however, an amount in the order of $1M-2M per year appears to be the proper order of magnitude.

Another question of some importance which needs to be addressed is the structure of the effort to be mounted. There appear to be two reasonable possibilities: the establishment of a small number (perhaps two or three) of major centers for

computers in education, or the support of five to ten groups nationally. In either case, it is essential that the groups which are established remain in close contact with one another and that there be rapid communication of findings to the educational community.

This author is not in a position to place the expenditure of $1M-2M per year into the national priorities; however, it is clear that if this level of expenditure is not made available, computers in education will continue to "wander in the desert" with an occasional Bork or Dwyer emerging for a short time. If such expenditures are made, educators will enter an exciting new era.

One final observation is worth making in connection with this project. During the information-gathering phase of this effort, this author frequently found himself in the role of a bee, picking up pollen (knowledge) at one place, and dropping it off at another. At each site which he visited, the author picked up some new knowledge and transmitted his findings to the group which he visitied. This role of short-term travelling visitor is very interesting, and potentially very useful for cross-fertilization. It may be that the National Institute of Education should consider appointing a small number of such visitors each year to gather and transmit knowledge at the forefront in some area of interest to the Institute.

APPENDIX A: INDIVIDUALS AND GROUPS CONTACTED

In order to prepare this report, it has been necessary to gather information from many sources, including discussions with a variety of experts in microcomputers and in video-disc systems. In order to assist the reader of the attached report in its evalution, the people contacted and places visited are listed below in rough chronological order.

1. First West Coast Computer Faire, San Francisco, April, 1977.
2. National Computer Conference, Dallas, Texas, June, 1977.
3. National Institute of Education, Washington, D.C.
   Arthur Melmed
4. General Instrument Corp., Hicksville, N.Y.
   Richard Burger, Assistant to Chief Engineer
   Ronald Stephens, Product Line Manager, Microcomputers and Video Games.
   Matt Lavell, Manager, Microcomputers.
   Henry W. Pechar, Applications Group Manager
5. Computer Teaching Research Center, Brigham Young University, Provo, Utah.
   Robert Mendenhall
   Dr. Victor Bunderson
6. Billings Computer Co., Provo, Utah
   Roger Billings, President
7. Dymax Corp., Menlo Park, California
   Don Inman
   Leroy Finkel
8. Robert Albrecht, independent consultant, teacher, Menlo Park, California.
   Dragon Emeritus of People's Computer Co.
9. People's Computers, Menlo Park, California
   Phyllis Cole, Editor
10. Dr.Dobbs Journal of Computer Calisthenics and Orthodontia, Menlo Park, California
    James Warren, Editor

11. Learning Research Group, Xerox Palo Alto Research Center, Palo Alto, California

    Dr. Alan Kay, Director

12. National Semiconductor Co., Santa Clara, California

    Philip Roybal

13. Commodore Business Machines Co.,Palo Alto, California

    Charles Peddle, Chief Engineer, PET project
    Terry Lauderau, Software Manager

14. Physics Computer Development Project, University of California at Irvine

    Dr. Alfred Bork, Director

15. National Science Foundation, Washington, D.C.

    Dr. Andrew Molnar

16. MCA Laboratoris, MCA Disco-Vision, Inc., Torrance, California

    Ray Dakins, Department Head, Video-Disc Systems

17. Radio Shack Store, Huntington,N.Y.

    Chris Daly, Store Manager

18. Tandy Computer Co., Fort Worth, Texas

    Donald French, Software Manager, TRS-80

19. Army Research Institute, U.S.Army, Alexandria, Virginia

    James Baker

20. Philips Laboratories, Division of North American Philips Corp. Briarcliffe, N.Y.

21. North American Philips Corp., New York City, N.Y.

    Robert Cavanagh

22. Bolt, Beranek, and Newman, Cambridge, Mass.

    Dr. Wally Feuerzeig

23. Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

    Dr. Peter Jassell

24. Project Solo and Project Soloworks, University of Pittsburgh,
Dr. Thomas Dwyer, Director Pittsburgh, Pa.

25. Creative Computing, Morristown, N.J.
David Ahl, Publisher

26. Personal Computing Conference, Atlantic City, N.J., August, 1977.

APPENDIX B: EXPERIENCE OF LUDWIG BRAUN

Ludwig Braun currently is a Professor of Engineering and Assistant Director for Educational Technology of the National Coordinating Center for Curriculum Development (NCCCD) at the State University of New York at Stony Brook. In NCCCD, his responsibility is to develop applications of computers and other technological devices in pre-college curricula in science and mathematics. The purpose of introduction of these technologies is to increase student learning directly and, by increasing student motivation, indirectly.

He has been actively engaged in exploring applications of computers in education at the pre-college and college levels since 1965. During the period from 1967 to 1976, he was, first, responsible for the computer effort within the Engineering Concepts Curriculum Project, and, then, Director of the Huntington Computer Project. The latter project was one of the major computer-curriculum projects funded by the National Science Foundation (NSF). The total funding for this project was about $1M. The materials developed by this project were focussed on biology, physics, and the social sciences; although some materials were developed in chemistry, earth sciences, and mathematics as well.

In addition, he has been a consultant to the Technological Innovations in Education group at NSF, and has acted as an advisor to many school systems on introducing computers into their academic programs.

Braun joined the microcomputer revolution in its "early" days. In the Spring and Summer of 1975, he and his son John built an Altair 8800--which actually worked! He also was a participant in the invitational HumRRO Conference on the Effect of LSI technology on Education held at Airle House in September,1975.

He has made presentations on educational applications of computers at many national, regional, and local educational meetings, and has written extensively on the subject.

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40. Finseth, Craig A., A Taste of APL, Creative Computing, July/August, 1977, vol.3, no. 4, pp. 96-99.

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An additional paper has come to the attention of this author since this report was completed. The abstract is quoted below:

> "This report reviews the literature on instructional graphics and the implications of the findings in terms of graphic displays for computer assisted instruction. It was concluded that the inherent value of graphics for instruction is unsubstantiated and that future research should systematically examine the use of graphics as a function of task requirements, subject matter content and learner characteristics."

This author has not had time to evaluate this paper, however it appears to have important impact on the present report. The paper is:

Moore, M.V. and L.H. Nawrocki, The Educational Effectiveness of

Graphic Displays for Computer Assisted Instruction, 31 March, 1976.

The paper may be obtained from:

Department of the Army

Organizations and Systems Research Laboratory

U.S. Army Research Institute for the Behavioral and Social Sciences

5001 Eisenhower Avenue

Alexandria, VA. 22333